11T Magnet Development Effort with CERN

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Technical Division
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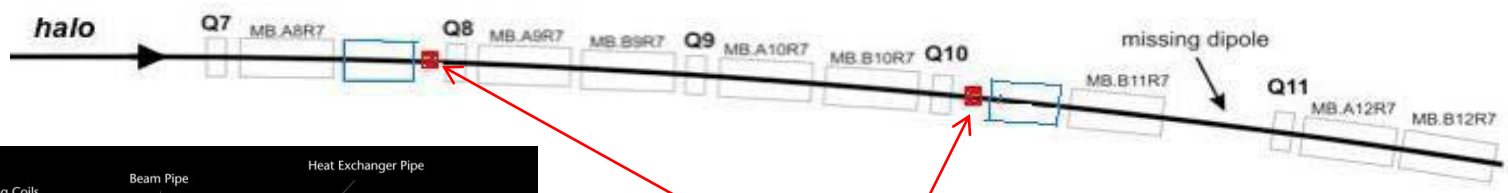
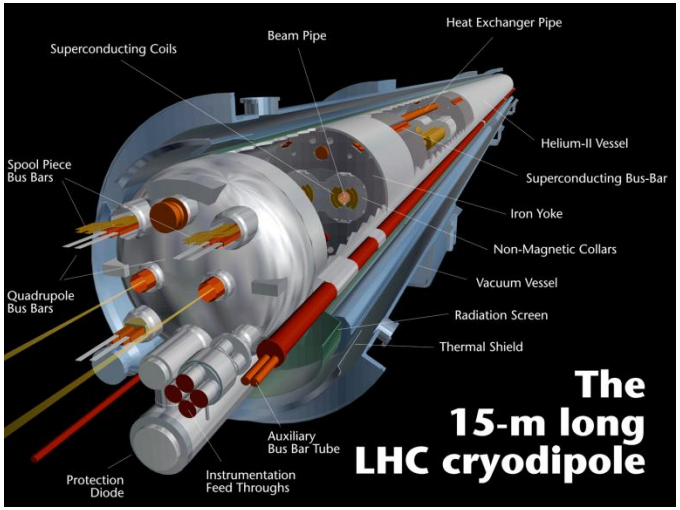
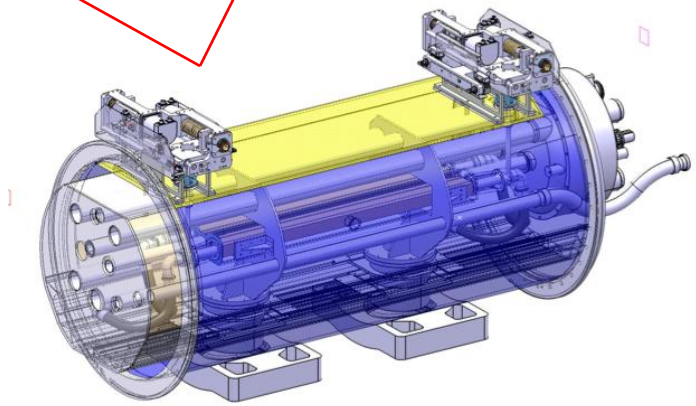
Motivation

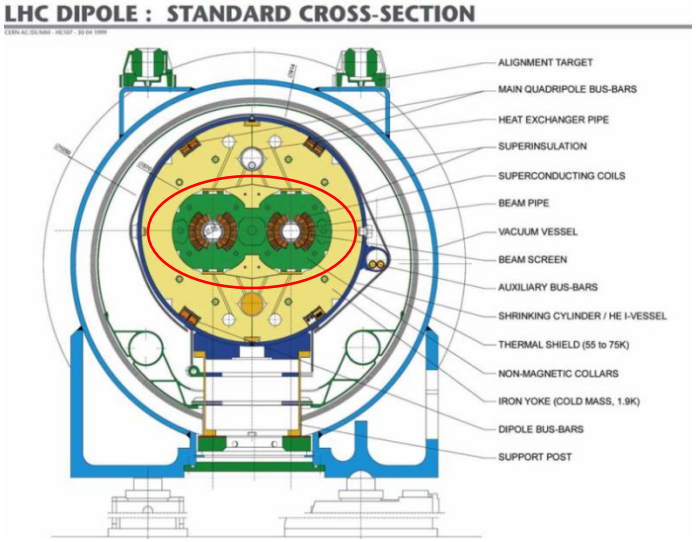






- **LHC collimation system upgrade (2012-2016).**
- **Phase II goal: intercepting off-momentum protons from single-diffractive scattering on cold collimators in the DS sections downstream of the collimation areas.**
- **11 T 11-m long double-aperture dipoles compatible with the LHC lattice and major systems provide the required space for cold collimators.**

Design Constraints and Feasibility



- **Same nominal current -11850 A**
- **Same cold mass OD - 570 mm**
- **Same distance between apertures -197 mm**
- **Nominal field – 11+ T**
- **20% operational margin at 1.9 K - B_{max}=13.2 T**

❖ **Independent studies at CERN and Fermilab**

- **The nominal field of 11+ T at 11.85 kA with 20% at 1.9 K is possible with Nb3Sn coil**
- **the magnetic length varies between 10.7 and 10.5 m, thus resulting in dipoles 3.6 to 3.8 m shorter than the standard LHC dipole**

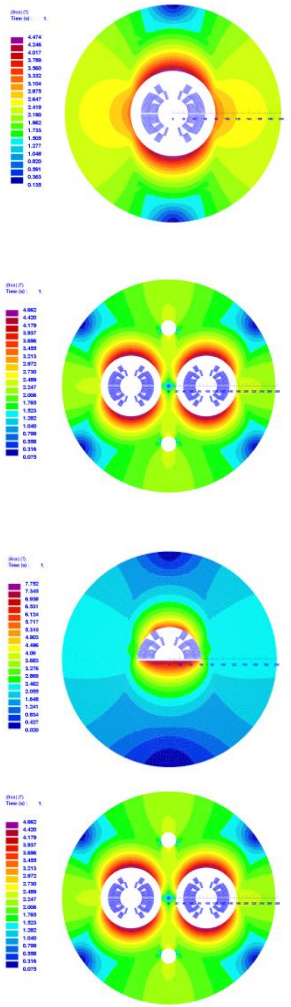
❖ **Nb3Sn magnet technology: available at Fermilab**

Challenges and Approaches

- **First 2-in-1 Nb_3Sn magnet =>**
  - **Common yoke, separate collared coils**
- **Orbit sagitta => larger aperture**
  - **56 mm => 60 mm**
- **Long length ~11 m =>**
  - **2 cold masses each 5.5-m long**
- **Field quality =>**
  - **small filaments (D_{eff}~30 μm) + passive correction to reduce persistent current effect**
  - **SS core to minimize eddy current effect**
  - **collar/yoke interface and holes to reduce iron saturation effect**
- **Larger Lorentz forces**

Activities and Deliverables

- **FY11-12: Development and test of 60-mm single-aperture 2-m long 11 T DS dipole demonstration model**
- **FY12: Fabrication and test of two 2-m long collared coils for the first 2-in-1 DS dipole model**
  - **2-in-1 cold mass assembly and test at CERN**
- **FY13: Fabrication and test of the first 5.5-m long dipole coils for DS dipole prototype**
- **FY13-14: Fabrication of 5.5-m long collared coil for the first 2-in-1 prototype**
  - **Long prototype assembly and test at CERN**



Collaboration with CERN, technology transfer.

Outcome

- **In case of a successful demonstration and selection of these magnets for the LHC phase II collimation system upgrade, planned in 2016, a joint FNAL-CERN project to fabricate five (or more) 11 T 11-m long dipoles will be proposed for FY14-16**
  - **the first use of Nb_3Sn magnet technology in real accelerator**
- **These magnets can be also used in the future to provide space in the LHC lattice for different insertion devices (dynamic collimators, correctors, instrumentation, etc.).**

Program Approval

Fermilab

Fermi National Accelerator Laboratory
Technical Division
Headquarters
P.O. Box 500 Mail Stop 316
Batavia, IL 60510
Phone: (630)840-4641

September 2nd, 2010

To: Stuart Henderson, Associate Director for Accelerator

From: Giorgio Apollinari, Technical Division Head

Subject: Proposal for Development of 11 Tesla LHC Dipoles

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White Paper on

CERN/FNAL Collaboration for the Development and Construction of Nb3Sn Dipoles for the LHC upgrades

G. Apollinari, A. Zlobin, Technical Division, Fermilab

1 Nb3Sn Accelerator Magnets Development

Nb3Sn has been recognized as a viable superconductor for the construction of accelerator magnets since its discovery. In the last decade, the DOE has supported, through its OHEP branch, several R&D efforts aimed at the development of high-performance Nb3Sn strand advanced high-field accelerator magnets, in particular focusing on the quadrupoles to be used at the Large Hadron Collider (LHC) for luminosity increase toward the end of the present decade (2020). This latter effort, called LARP (LHC Accelerator Research Program) has involved the US national labs (LBNL, BNL, SLAC and Fermilab) and has recently successfully achieved the goal of building a ~4 m long 90-mm aperture Nb3Sn quadrupole reaching the field goal of 200

CERN Support

Subject: Letter of Support for Magnet Development Program
Date: Fri, 21 Jan 2011 14:12:56 +0000
From: Steve Myers <Steve.Myers@cern.ch>
To: michael.procario@science.doe.gov <michael.procario@science.doe.gov>
CC: bruce.strauss@science.doe.gov <bruce.strauss@science.doe.gov>, lk.len@science.doe.gov <lk.len@science.doe.gov>, stuarth@fnal.gov <stuarth@fnal.gov>, apollina@fnal.gov <apollina@fnal.gov>, Lucio Rossi <Lucio.Rossi@cern.ch>, Paul Collier <Paul.Collier@cern.ch>, Frederick Bordry <Frederick.Bordry@cern.ch>, Eric Prebys <prebys@fnal.gov>, Acc-Tec-Director Office <Acc-Tec-Director.Office@cern.ch>

Dear Mike,
Please find attached th
will send a signed versi
Regards Steve

Steve Myers
Director of Accelerators
CERN
1211 Geneva 23
Tel. 0041227673406
e-mail Steve.Myers@cer

In order to avoid the large over-heads associated with the removal and reinstallation of such a large number of superconducting magnets, CERN has recently considered the replacement of the existing LHC dipoles in question by shorter, higher field ones. The magnet groups from FNAL and CERN are already working together on a project called "11T-11m LHC dipole". This project is based on the advanced Nb^3Sn technology program of DOE-LARP. In particular the FNAL team has a well-recognized technical expertise for dipole magnets to be operated at around 10-11 T and 50 mm aperture.

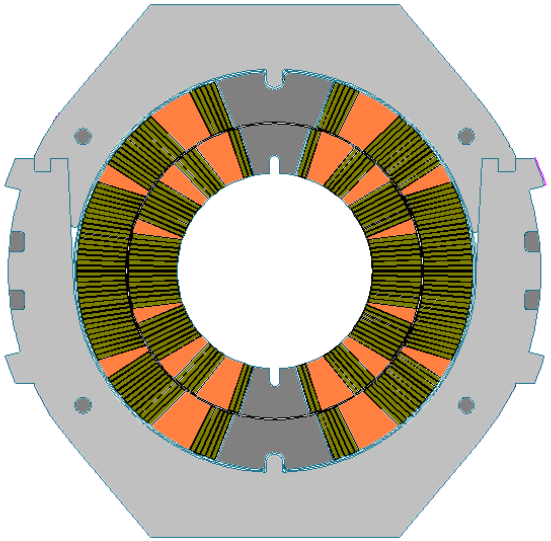
This letter strongly supports this program as a key component in the future upgrade of the LHC.

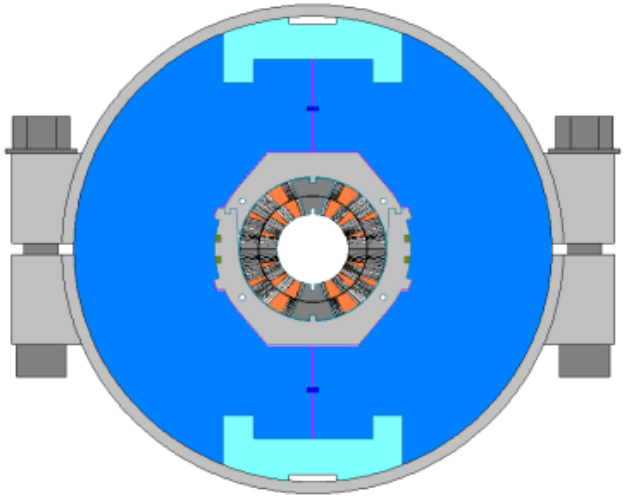
Presently, the total number of 11T-11m LHC dipoles needed is 8; i.e. 2 per side of each of the interaction points 3 and 4. A new scheme is presently being studied which could reduce the number of dipoles to 4, however, the feasibility has not yet been proven.

It is well known that the development of technically complicated components such as SC magnets requires a long lead time (from conception to actual hardware installation in the tunnel). **Consequently we strongly support the present program for the construction of a single bore, 1 m long model, which could demonstrate by 2011 the feasibility of such a magnet. We consider this program to be a significant contribution to the LHC and its upgrade, and we hope that DOE endorses the FNAL proposal of collaboration with CERN on such topic.**

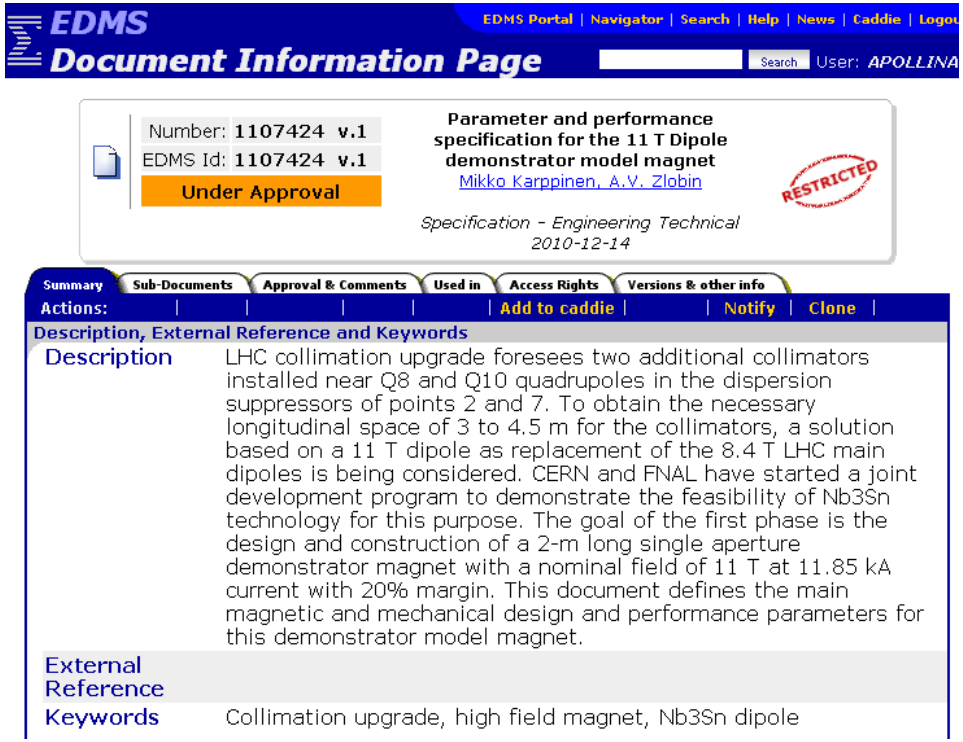
Design and Parameters

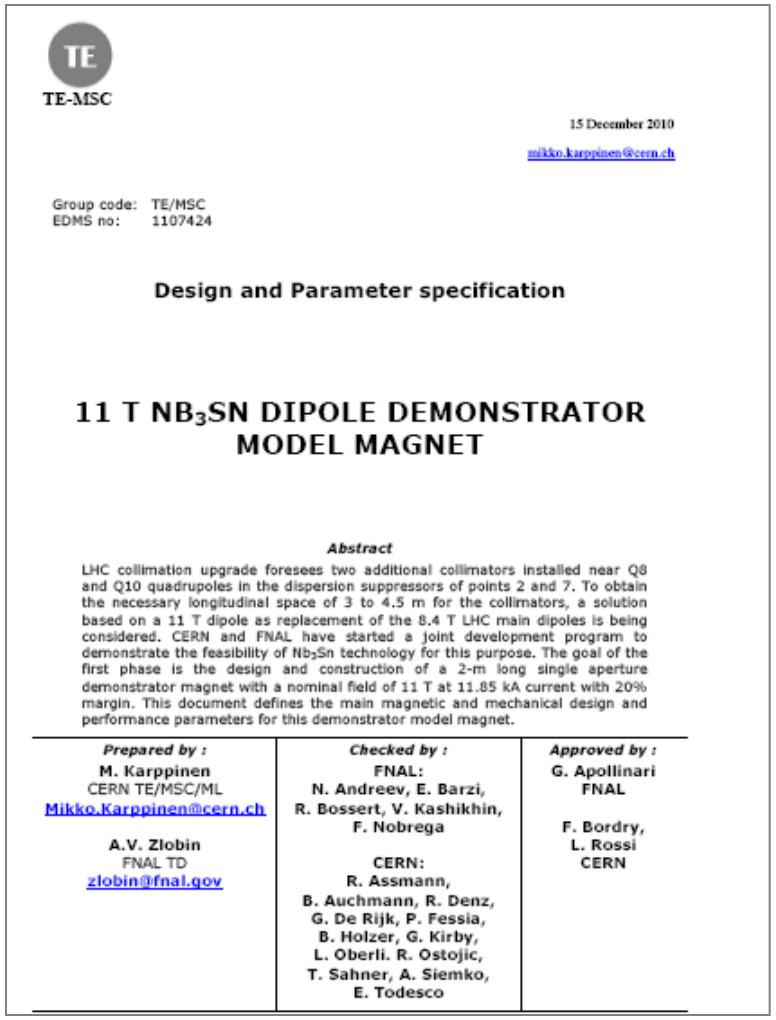
- Strand: 0.7 mm RRP-108/127
- Cable: 40-strand 14.7x1.2 mm2
- Coil: 2-layer 7-block (CERN)
- Coil aperture: 60-mm
- Collar: stainless steel 20-mm
- Yoke: OD=400-mm, 2-piece
- Skin: 12-mm stainless steel
- Cold mass length 1.97 m
- B_{nom}=11.31T @ I_{nom}=11.85kA
- B_{max}=13.74T @ I_{max}=14.39kA
- Margin: B_{max}/B_{nom}=1.215





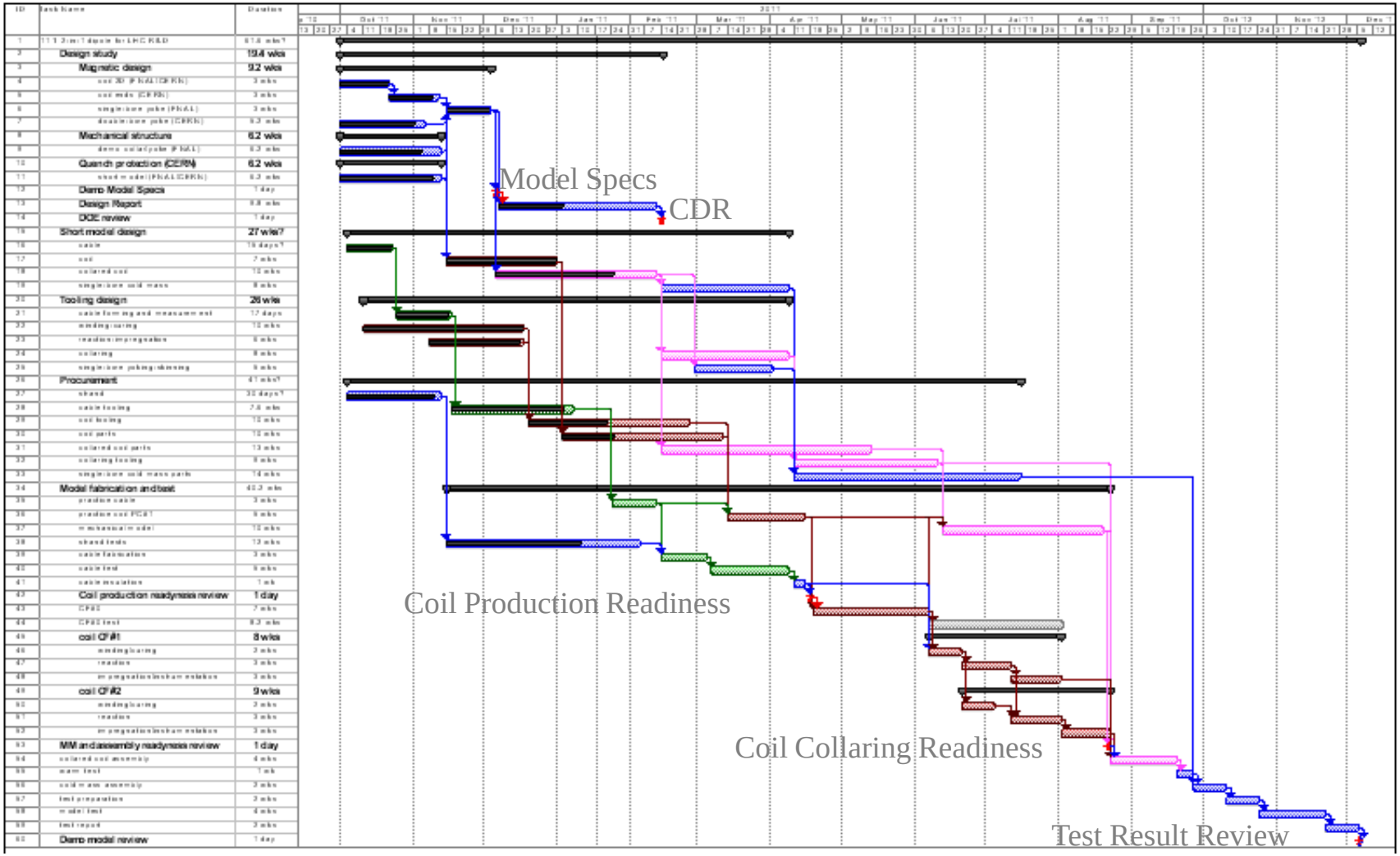
Specifications





- **Specs in CERN EDMS**
- **Evaluate test results**

Schedule & Milestones



❖ **Good progress in October-January**

Is success possible?

- **Specific features of this program, besides technical challenges, are its limited development time and resources**
- **The success is possible**
  - **high skill of Fermilab's magnet group**
  - **previous successful experience with the 10-12 T Nb_3Sn dipoles and quadrupoles**
  - **available infrastructure and tooling**
  - **established productive collaboration with CERN**